PERCEPTUAL ORGANIZATION IN THE RAT

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The course of modern research on the problem of discriminative learning has been markedly influenced by contradictory conceptions of the nature of perceptual organization. Lashley (10, 11) and Krechevsky (8, 9) have maintained that even in the rat perception is selective and relational in character, while Spence has insisted upon a purely additive organization, contending that discriminative behavior is a summative function of excitatory and inhibitory properties independently acquired by sensory components (15, 16). Although Spence's theory has been strongly supported by the results of experiments on continuity, transposition, and stimulus-generalization (1, 6, 17, 18), several recent investigations provide evidence for the operation of non-additive integrating mechanisms in perception. Saldanha and Bitterman (14) report that, under certain conditions at least, the progress of discriminative learning is facilitated by opportunity for direct comparison of the stimuli to be discriminated, a result which has been confirmed by Coate (3) in the context of a continuity experiment. Bosworth and Bitterman have found, conversely, that the relational introduction of *irrelevant* components *retards* discrimination (2). These results fit nicely into the conceptual framework developed by Lashley, but contradict deductions from the postulates of Spence. Neither theory, however, can deal with the results of an experiment by Weise and Bitterman (19) which suggested the greater fundamental simplicity of the successive as compared with the simultaneous type of discriminative problem. Taken together, these investigations suggest a distinction between two non-additive processes of perceptual organization—a primitive, diffuse situational process (configurational learning), and a more abstract, selective, transcontextual one (relational learning). The research to be reported here provides further support for the validity of this distinction.

The logic of the investigation can best be set forth in relation to the design of the experiment which is illustrated in Table I. Two rats, A and B, are trained in Lashley's jumping apparatus. The animals are matched for speed of learning Problem I, which is the same for both. When presented with two black-and-white vertically striped cards differing in width of stripe (Situation 1), the animals are rewarded for jumping left to the thin stripes and punished for going right to the thick stripes. The lateral position of these cards is never reversed, so that the thin stripes always appear at the left. When presented with two gray cards differing in brightness (Situation 2), the lighter card always being situated at the left, the animal is rewarded for jumping right to the dark card and punished for going left to the lighter card. The two pairs of cards are presented alternately in random fashion until the problem is mastered. Now training on Problem II is begun. This problem involves the same cards as the first, but the lateral inversions of the pairs employed in Problem I also are introduced, making a total of four different perceptual situations rather than only two as in the first problem. The situations are presented equally often in random sequence, and in this stage of the experi-

TABLE I

ILLUSTRATION OF THE DESIGN OF EXPERIMENT II

Problem	Situation*	Rewarded response	
		Rat A	Rat B
I	1. thin/thick	left	left
	2. light/dark	right	right
II	1. thin/thick	left	right
	2. light/dark	right	left
	3. thick/thin	left	right
	4. dark/light	right	left

* "Thin" and "thick" refer to black-and-white striped cards differing in width of stripe; "light" and "dark" refer to plain gray cards differing in brightness. "Thin/thick" means thin stripes in the left window of the jumping apparatus and thick stripes in the right window.

ment the two animals are trained differently. Rat A is required to jump left whenever the striped cards are presented, irrespective of lateral position, and to jump right when the gray cards appear, while Rat B is required to go right to the stripes and left to the grays. How will the performances of the two animals compare?

Spence's theory leads to the prediction that the animals will encounter equal difficulty. From an analysis of Problem I in terms of afferent components, we must conclude that it can only be mastered if thinness and darkness acquire dominantly excitatory properties while thickness and lightness acquire dominantly inhibitory properties; that is, the two thicknesses and the two brightnesses must be functionally differentiated. In Problem II, therefore, the animals should respond in terms of these differences in all four situations. The position reversals cannot from this point of view be significant, since leftness and rightness have been equally often rewarded in Problem I and any residual differences in excitatory and inhibitory value must be negligible compared to the differences in the values of other components when the criterion of learning for the first problem has been reached. (In the experiment to be described residual position differential is randomized by the use of two *groups* of animals rather than two individuals.)

It follows, then, that the initial tendency of the two animals to jump to the thin stripes should be the same in Situations 1 and 3, and the initial tendency to jump to dark gray should be the same in Situations 2 and 4. Both learning curves, therefore, should begin at the chance (50 per cent) level, although the errors of Rat A should be made in Situations 3 and 4 while the errors of Rat B should be made in Situations 1 and 2. Furthermore, a strictly summative theory suggests that neither animal will ever master Problem II. If each afferent "component" is assigned an adience-value which is defined as the algebraic sum of its excitatory and inhibitory characteristics, the following inequalities must obtain at the time of mastery (P_1 and P_2 represent the values of the two positional components, T_1 and T_2 represent the two thicknesses, and G_1 and G_2 represent the two grays):[1]

$$
\begin{aligned}
T_1 + P_1 &> T_2 + P_2 \\
G_1 + P_2 &> G_2 + P_1 \\
T_2 + P_1 &> T_1 + P_2 \\
G_2 + P_2 &> G_1 + P_1
\end{aligned}
$$

Summing these inequalities, we arrive at the following invalid conclusion:

$$
\begin{aligned}
T_1 + T_2 + G_1 + G_2 + 2P_1 + 2P_2 &> \\
T_1 + T_2 + G_1 + G_2 + 2P_1 + 2P_2
\end{aligned}
$$

A theory which assumes a purely additive relation among afferent components cannot, therefore, predict that errorless

[1] In the case of Rat A, Table I, T_1 equals thin, T_2 equals thick, P_1 equals left, P_2 equals right, G_1 equals dark, and G_2 equals light.

performance on Problem II is possible.

Despite the fact that Lashley's theory differs radically from that of Spence, it leads in this instance to much the same prediction. From the point of view of Lashley, in Problem I the animals have learned to choose the thinner stripe and darker gray, and this relational set should be manifested during the initial stages of training on Problem II. Once again, therefore, it must be deduced that both learning curves will begin at the 50 per cent level owing to the errors of Rat A in Situations 3 and 4 and the errors of Rat B in Situations 1 and 2. While Lashley's theory provides no basis for predicting that Problem II is impossible of solution, neither does it specify the processes which are involved in the mastery of such a problem. If selective, relational perception is fundamental to all discriminative learning, the solution of Problem II must require that an extremely complex pattern of conditional sets be developed. Although certain components of this pattern might conceivably appear during training on Problem I, it would seem more reasonable to assume that the animals do not resort to such elaborate "attempts at solution" (10, p. 243) in situations to which a completely satisfactory adjustment can be made on a more primitive level. If this assumption is correct—that is, if the animals achieved only uncomplicated relational preferences (for thinner and darker) in Problem I—they should progress at the same rate on Problem II.

A quite different prediction is suggested by the work of Weise and Bitterman (19). Although the experiments of Saldanha and Bitterman (14) demonstrate that stimulus-cards such as those employed in Problem I may, *under certain conditions,* be perceived relationally, the research of Weise and Bitterman indicates a second, more primitive configurational process which takes precedence over the first when circumstances permit. From this point of view the two card-pairs (situations) of Problem I may function as diffuse or loosely organized wholes to which the animals learn to respond differentially (7). Since this primitive level of organization suffices for the solution of the problem, a more articulated organization, involving the differentiation of the two cards of each pair, will not readily be developed. If this formulation is correct—that is, if the animals learn in Problem I to go left to stripes (undifferentiated) and right to grays (also undifferentiated)—their performances on Problem II should differ significantly. If the cards of each pair remain completely undifferentiated at the termination of training on Problem I, the performance of Rat A on Problem II will be errorless, while Rat B may be expected to make many errors. In general, the difference in performance on Problem II provides an inverse index of the degree of differentiation developed in Problem I.

Before the results of this experiment are presented, a preliminary experiment which led to its design will be described. The general form of the preliminary investigation is schematized in Table II. Suppose that two animals are trained on a succession of three problems in Lashley's jumping apparatus. The animals are matched for performance on Problem I which is the same for both. This problem involves two situations, black/white and horizontal/vertical. In Situation 1 the animals are rewarded for going right to the white card and punished for going left to the black, while in Situation 2 they are rewarded for jumping left to the horizontally striped card and punished for jumping right to the vertical stripes. Problem II involves two situations, the previously encountered black/white and its lateral inversion,

TABLE II

ILLUSTRATION OF THE DESIGN OF THE PRELIMINARY EXPERIMENT (I)

Problem	Situation*	Rewarded Response	
		Rat A	Rat B
I	1. black/white	right	right
	2. horizontal/vertical	left	left
II	1. black/white	right	left
	3. white/black	right	left
III	2. horizontal/vertical	left	right
	4. vertical/horizontal	left	right

* "Black" and "white" refer to homogeneous black and white cards; "horizontal" and "vertical" refer to horizontally and vertically striped black-and-white cards. "Black/white" means that the black card was situated in the left window of the jumping apparatus and the white card was in the right window.

white/black. Rat A is rewarded for jumping right in both situations and Rat B for jumping to the left.

On the basis of the considerations already outlined, the theories of Spence and Lashley lead to the prediction that the two rats will master Problem II at the same rate. In Problem I both animals should acquire a preference for the white card which should be manifested in Problem II. The lateral position of this card should make no difference, since, in the language of Spence, each spatial component has been equally often rewarded in Problem I, and, in the language of Lashley, there is no reason for assuming that the spatial relation has been perceptually selected as relevant to the solution of Problem I. It follows from both theories, therefore, that the animals should respond initially at a chance level on Problem II (although the errors of Rat A will be made in Situation 3 while the errors of Rat B will be made in Situation 1), and that both animals should then proceed to a mastery of the problem at identical rates. Configurational theory leads, on the other hand, to a quite different prediction. From this point of view the mastery of Problem I may involve, not a functional differentiation between black and white and between vertical and horizontal, but a more diffuse differentiation between the two perceptual situations as such. It is not implied that, following training on Problem I, Situation 3 will be fully equivalent to Situation 1, but only that the two situations are enough alike so that the animals will tend to respond to Situation 3 as they have learned to respond to Situation 1 (*situational generalization*). According to this theory, Rat A should have a considerable advantage while Rat B should be placed at a disadvantage, because in Situation 3 *both* animals should tend to jump right (to the black card) even though jumps to this card have previously been punished consistently.

As it turned out, however, differences in the performance of the rats on Problem II were not clear-cut, but only suggestive, and Problem III was introduced. Again on this problem the theories of Spence and Lashley predict no difference in rate of learning. Both animals must overcome preferences for the horizontally striped card established in Problem I and both animals must also overcome the position preferences established in Problem II. Configurational theory, on the other hand, suggests once more that Rat A will have a considerable advantage. Results for both problems will be presented following a detailed description of the procedure employed in the experiment.

EXPERIMENT I (PRELIMINARY)

Subjects: Twenty-two experimentally naive, male rats of the Wister strain, ranging in age from 120 to 160 days, were employed in the experiment.

Apparatus: A two-window jumping apparatus, of the kind devised by Lash-

ley, was used. The windows were 5½ in. high and 5½ in. wide and separated by a wooden wedge 1¼ in. wide which extended 1¾ in. in front of the windows. The wedge served to discourage jumping to the strip between the two windows. The distance between the jumping platform and the windows was variable. The platform itself was covered with a grid through which weak shock could be administered to break resistance to jumping. A correct response admitted the animals to a feeding platform behind the windows, while an incorrect response precipitated the animals into a burlap net 3 ft. below. The stimulus cards appeared against a gray background.

Procedure: The major phases of the experiment were preceded by a period of preliminary training. The animals were fed on the feeding platform for several days and then allowed to walk through the open windows to food from the jumping platform which was moved up close to the windows. They were then trained to jump through gradually increasing distances, first to the open windows and then to unobstructed gray cards. Manual guidance was employed to ensure that the animals would jump equally often to both windows. Whatever position preferences were manifested during this stage of training were duly recorded. Throughout the experiment the rats were kept on a 24-hour feeding schedule.

Problem I: Following the preliminary training the animals were presented with Problem I, which is illustrated in Table II. Four stimulus-cards were employed, one black, one white, and two black-and-white striped cards, one horizontally and the other vertically, the width of each striation being ½ in. Each animal was trained to jump in one direction to *one* of the two possible spatial arrangements of the black-and-white cards (Situation 1) and in the opposite direction to *one* of the two possible spatial arrangements of the striped cards (Situation 2). There were thus eight different training combinations to which the animals were randomly assigned. Each rat was given ten trials per day, five to each of the two situations which were alternated following the Gellerman series (5). The non-correction method was employed throughout the experiment, and training was continued to a criterion of two errorless days. After this criterion was reached, each rat was given four days (40 trials) of over-learning.

Problem II: As the animals finished Problem I they were assigned to either of two groups, I and II, matched for rate of learning, and then trained on Problem II, which is illustrated in Table II. This problem involved the two situations black/white and white/black. Animals in Group I were trained to jump to both situations in the *same* direction as they did to the black-white pair in Problem I, while the animals of Group II were trained to jump in a direction *opposite* to that which was rewarded in the black-white situation of Problem I. For purposes of illustration it may be noted that Rats A and B of Table II belonged to Groups I and II, respectively. Again in this stage of the experiment, ten trials per day were given, the two situations being alternated randomly, and training was carried to a criterion of two errorless days.

Problem III: Following Problem II, each animal was trained on Problem III (see Table II). This problem involved the two situations horizontal/vertical and vertical/horizontal. In each of these situations, each animal was rewarded for jumping in a direction opposite to that which was rewarded in Problem II. Ten trials per day were given, five to each of the two situations which were alternated randomly, and

the criterion of learning was two errorless days.

Results and Discussion

The course of learning for each group on each of the three problems is plotted in Fig. 1. The results for two animals of Group II which died during the early stages of Problem II were not used in computing these curves. The two groups learned Problem I at rates which are roughly comparable, the mean error score for Group I being 34.6 and that for Group II being 39.3. The over-all performances of the two groups on Problem II were also quite similar, the mean error scores being 6.5 and 8.3, respectively. The difference does not approach statistical significance, a result which can be deduced from the theories of Lashley and Spence. On the first day of Problem II, however, the scores of the two groups tended to diverge in a manner which cannot be predicted by these theories. On that day Group I made a mean of 2.35 errors while the mean error score of Group II was 4.88. By Festinger's test (4) the difference is significant at about the five per cent level of confidence. Three animals of Group I actually made no errors at all on Problem II, and two made only one error each. No animal of Group II matched this performance. These results suggest that a real difference existed between the two groups which was masked, insofar as over-all performance on Problem II is concerned, by the extreme simplicity of that problem.

This interpretation is borne out by the results for Problem III. The animals of Group I learned rapidly while those of Group II showed a rigidly persistent tendency to jump in the direction rewarded in Problem II. The difference between the mean error scores of the two groups for the eight-day period of training (15.4 and 58.0, respectively) was significant beyond the one per cent level of confidence (Festinger's test).

The results of this preliminary experiment may be understood in the fol-

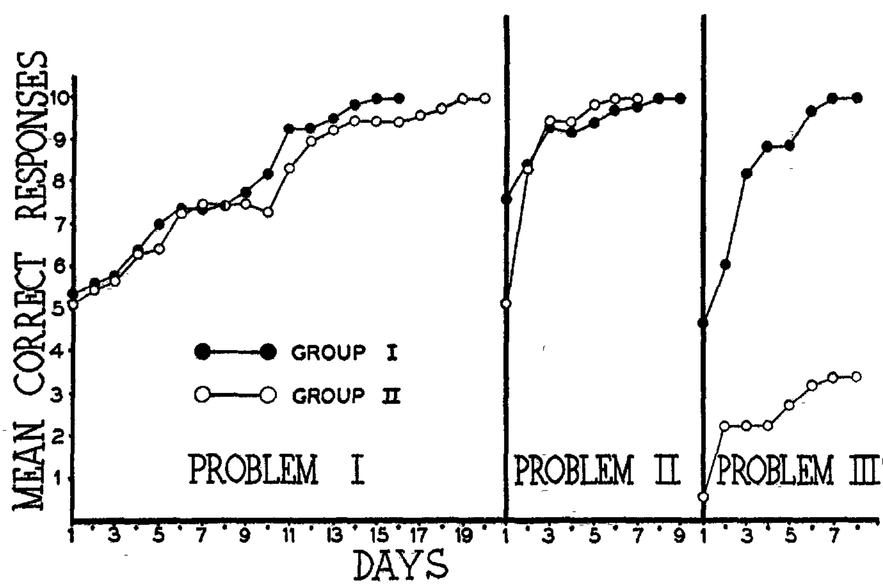

FIG. 1. Learning curves for the three problems of Experiment I.

lowing terms: In Problem I the animals learned to respond differentially to the two situations (black-white and horizontal-vertical) which were, to some extent at least, perceived as undifferentiated wholes. These configurations did not, however, remain totally undifferentiated, and there was some tendency for the positive and negative cards of each situation to become functionally distinct, as was revealed by the fact that some animals in each group continued for many trials on Problem II to jump to the positive brightness of Problem I irrespective of lateral position. The configurational effect was, nevertheless, manifested in a tendency toward *situational generalization* in Problem II (jumping in the previously rewarded direction to both black-white situations) which led to a signficant difference between the first day's error scores. For Group I, situationally generalized responses were rewarded in Problem II, and for this reason the training on Problem II was partially congruent with that in Problem I, as was also the training on Problem III. For Group II, however, the training on Problem II was congruent with neither of the tendencies established in Problem I and the consequent frustration led to a rapidly developed but rigid position-fixation which persisted in Problem III (12). For this reason Problem III was significantly more difficult for Group II. It should be noted, however, that in the case of Group I a generalized position-preference must be assumed to have developed during Problem II and to have carried over to the third problem. There is no other way in which to account for the many errors initially made by these animals on Problem III. Our preliminary experiment, then, provides evidence for non-configurational or component-reactions both to brightness and to position of the sort required by current theories of discriminative learning. Only if we make the assumption of an additional, configurational process, however, can we account for all of the results of this experiment.

EXPERIMENT II

The second experiment was designed to demonstrate more clearly the configurational process revealed in the first. The conditions employed were chosen to minimize any tendency to respond in terms of particular aspects of the stimulus-situation which served to obscure the configurational response in the preliminary study. In the first place, new stimulus-cards were chosen with a view to making differentiation more difficult between the members of each pair. Further, Problems II and III of Experiment I were merged into a single second problem in order to forestall the development of obscuring positional reactions.

Subjects: Eighteen experimentally naive, male rats of the Wister strain, ranging in age from 120 to 160 days, were studied.

Apparatus: The Lashley jumping apparatus described in connection with the preliminary experiment was employed. The only change made was in the color of the background of the stimulus-cards, which was now flat black instead of mid-gray.

Procedure: The preliminary training was the same as that in Experiment I. The animals were adapted to the apparatus and taught to jump through a distance of nine inches to unfastened cards. The cards employed for this purpose were those to be rewarded in the first phase of the experiment. They were presented as pairs—the two positive stripes and the two positive grays. Manual guidance was used to break up any position preferences which developed. Throughout the experiment the animals were maintained on a 24-hour feeding schedule.

Problem I: Following the preliminary training the animals were trained on Problem I, which is illustrated in Table I. The stimulus-cards were two homogeneous gray cards differing in brightness and two black-and-white, vertically striped cards differing in stripe-thickness (¼ in. and ½ in., respectively). For each animal only two pairings were used, the animals being required to jump in one direction to *one* of the two possible arrangements of the striped cards (Situation I) and in the opposite direction to *one* of the two possible arrangements of the gray cards (Situation II). As in Experiment I, therefore, there were eight different possible training combinations and to these the animals were randomly assigned. Each rat was given 12 trials per day, six with each of the two situtions which were alternated according to modified Gellerman orders (5). The non-correction method was employed throughout the experiment and training was continued to a criterion of two errorless days.

Problem II: As the animals finished Problem I they were assigned to one or the other of two groups, I and II, matched for rate of learning, and then trained on Problem II which is illustrated in Table I. This problem involved four situations, the two encountered previously in Problem I and their lateral reversals. Animals of Group I were trained to jump in the *same* direction as before to each of the old situations as well as to its lateral reversal, while animals of Group II were trained to jump in a direction *opposite* to that previously rewarded in each of the old situations as well as in its lateral reversal. Table I may be consulted for purposes of clarification. Rat A, which belonged to Group I, was trained in Problem I to jump left to one of the stripe-situations and right to one of the gray-situations. In Problem II it was required to jump left to *both* stripe-situations and right to *both* gray-situations. Rat B, which belonged to Group II, was trained in the same way on Problem I, but in Problem II was required to jump right to *both* stripe-situations and left to *both* gray-situations. In short, situational generalization from Problem I to Problem II was

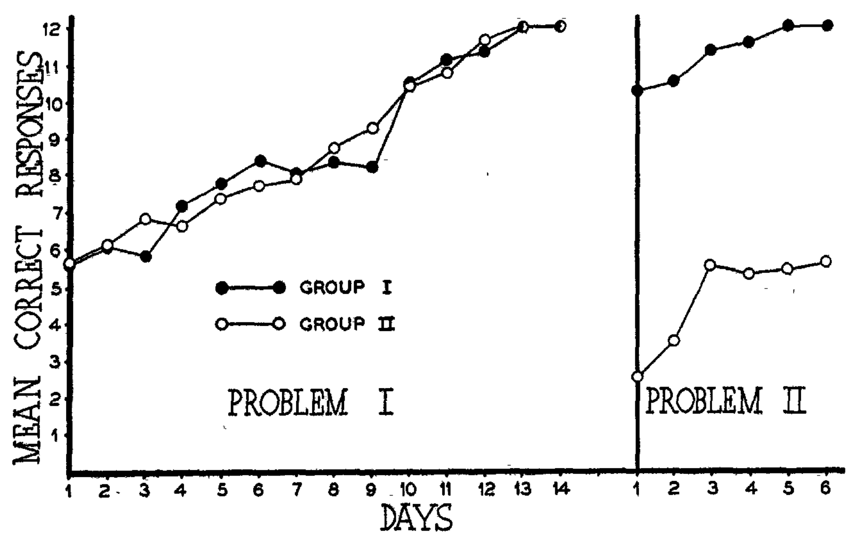

FIG. 2. Learning curves for the two problems of Experiment II.

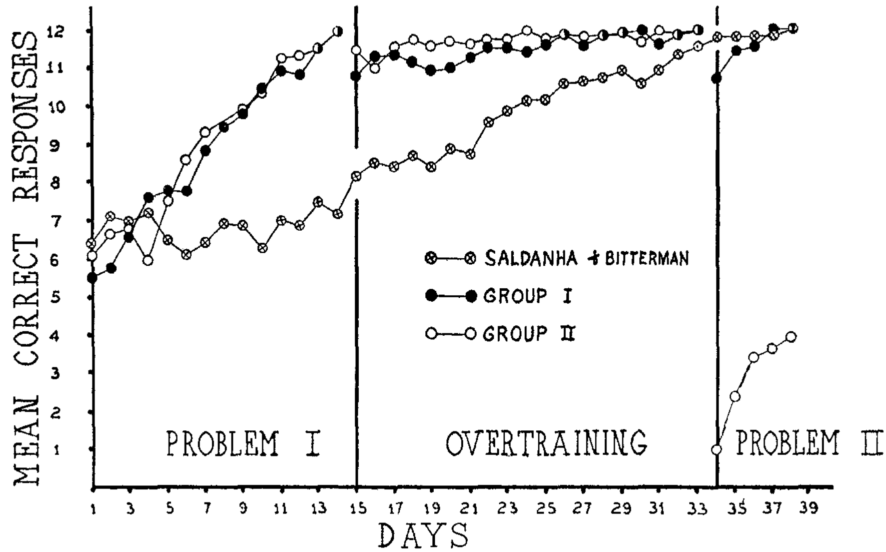

FIG. 3. Learning curves for the two problems of Experiment III and for the comparable four-situational problem of Saldanha and Bitterman (14).

rewarded for Group I and punished for Group II. Again in this stage of the experiment 12 trials per day were given, three to each of the four situations, and training was carried to a criterion of two errorless days.

Results and Discussion

The results of this experiment were unambiguous. An examination of the curves of learning plotted in Fig. 2 shows that although the two groups mastered Problem I in almost identical fashion, their performances on Problem II differed sharply. Both groups made a mean of 45.2 errors in the course of Problem I. On Problem II, the animals of Group I performed at a high level of accuracy from the very beginning and rapidly attained errorless performance. Of the nine animals in this group, three made no errors at all. Contrariwise, the animals of Group II made many errors on the first day and improved slowly. Not a single animal of this group had reached the criterion by the end of the sixth day of training, at which time, all of the animals of Group I having mastered the problem, the experiment was terminated. During the six days of training Group I made a mean of 4.1 errors, the difference being significant at well beyond the one per cent level by Wilcoxon's test (20). It may be concluded, therefore, that *the two members of each pair of cards encountered in Problem I remained almost entirely undifferentiated despite consistent reward and punishment.* The card-pairs of Problem I functioned as unarticulated wholes to which the animals learned to respond differentially (19).

A comparison of the results obtained in this experiment with those obtained by Saldanha and Bitterman (14) with a four-situational problem involving cards of the same characteristics suggests the development of qualitatively distinct perceptual organizations in the two experiments. The animals of Saldanha and Bitterman were exposed from the outset to *both* lateral arrangements of each pair of cards and trained to go to

one of the stripes and one of the grays, irrespective of lateral arrangement. All of the animals of the present experiment reached the criterion by the fourteenth day of training, at which time the animals of Saldanha and Bitterman were performing close to the chance level (Fig. 3). Furthermore, on the fifteenth day, when almost all of the latter animals were responding either randomly or in terms of position habits, the animals of the present experiment, shifted to Problem II, reacted differentially to stripe and gray situations.

EXPERIMENT III

The development of qualitatively distinct levels of perceptual organization in the two- and four-situational problems is revealed most clearly under conditions in which the animals of the two groups have equal experience with the stimulus-cards. The third experiment of this series was designed to provide such a comparison.

Subjects: Twenty naive, male rats of the Wistar strain, ranging in age from 100 to 150 days were studied.

Apparatus: The apparatus was the same as that employed in Experiment II.

Procedure: The procedure of Experiment II was duplicated with one important exception. After each animal had achieved one errorless day on Problem I it was given 19 days of over-training on that problem before being shifted to Problem II.

Results and Discussion

The results obtained in the third experiment resemble those obtained in the second. As the learning curves of Fig. 3 illustrate, the two groups of animals reached the criterion on Problem I by the fourteenth day (averaging 40.6 and 42.9 errors, respectively) and continued to perform at a high level of accuracy during the over-training phase (averaging less than half an error per animal per day). As in Experiment II, however, Problem II distinguished the groups, the difference in this case being greater than that previously obtained. When the deviation of each animal's error score from the chance value (six errors) on the first day of Problem II is used as an index of situational generalization, the values obtained in the third experiment prove to be significantly higher than those obtained in the second (Festinger's method, $p. < .01$). In the context of a two-situational problem, therefore, *increased frequency of reward and punishment may impair rather than facilitate differentiation between the members of each pair of stimuli.*

The performance of the animals of Saldanha and Bitterman (14), which were trained in a four-situational problem involving the same cards, is plotted in Fig. 3. By the thirty-fourth day of training these animals were performing very close to the 100 per cent level—that is, they were differentiating consistently between the two members of each pair of cards. After thirty-three days of reinforcement and punishment on the same cards in the two-situational problem, the animals of the present experiment responded with almost equal readiness to each member of each pair, although they discriminated consistently between gray and stripe configurations. This evidence points unmistakably to the development of qualitatively distinct levels of perceptual organization under the conditions of training being compared. The phenomenon of situational generalization which is revealed in experiments with two-situational problems implies the existence of a process of perceptual organization which is non-additive in nature in the sense that it cannot be reduced to the acquisition of functional properties by afferent components (as in the theory of Spence)

and which is non-differentiated in the sense of the relational theory of Lashley or the general approach-avoidance formulation of Nissen (13). The data of this experiment and the data of Weise and Bitterman suggest that aggregations of afferent components may function initially as loosely organized wholes out of which the perception of objects and relations is subsequently differentiated. The nature of the transition from this primitive level of organization to more complex levels remains for subsequent investigation.

SUMMARY

An experimental situation has been developed for which the two major contemporary theories of discrimination learning—the conditioning theory of Spence and the relational theory of Lashley—lead to essentially the same incorrect deduction. The results clearly reveal the operation of a primitive level of perceptual organization which is both non-additive and non-relational in character—a diffuse, undifferentiated configurational process which is functionally prior to the perception of objects and relations.

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